DIGITAL DEVICE WITH RECHARGEABLE BATTERY
AND RECHARGING METHOD THEREOF

CROSS REFERENCE TO RELATED APPLICATIONS

5   This application claims benefit under 35 U.S.C. §119 from Korean Patent Application No. 2003-112, filed January 2, 2003 in the Korean Intellectual Property Office, the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

10   Field of the Invention:

The present invention relates to a digital device with a rechargeable battery, and more specifically, to a digital device and a method thereof that enables the digital device not only to be operated using a power supply from an adapter, but also to simultaneously recharge a battery.

15   Description of The Related Art:

Generally, a conventional portable digital device, such as a handheld PC, is designed to be supplied with power from a battery therein, generally a rechargeable battery, for operating the device, as it is moved about. After the battery is discharged, the device can be operated again by recharging the battery through an adapter for a

20   predetermined time.

However, in the above referenced conventional portable digital device with the rechargeable battery, there is a problem in that the mode of the device should be converted to a recharge mode for recharging the battery when the digital device is supplied with power through the adapter. In addition, there is another problem in that an

25   expensive integrated circuit (IC) is required to separately control battery recharging, and this increases production costs. .

There is still another problem in the display means of the conventional portable digital device having the recharge and discharge function. The conventional portable

digital device has such a simple display means for displaying the state of recharge or discharge, that it cannot display the various states of the digital device to a user as they occur during the recharge and discharge of the battery.

SUMMARY OF THE INVENTION

In an effort to solve the problems as described above, it is an object of the present invention to provide an inexpensive battery re-charger with a small number of components.

In another aspect, the present invention includes a digital device capable of recharging a rechargeable battery, comprising a consuming current detect unit for detecting a consuming current input to the digital device through an adapter, a control unit, a recharging current detect control unit for detecting the battery recharging current as the battery is recharged, and a recharging control unit for regulating the consuming current to the rechargeable battery in proportion to a control signal, such as a pulse width modulation control signal, output from the control unit and the battery recharging current detected by the recharging current detect control unit.

In yet another aspect of the present invention provides a method for controlling recharging current of a rechargeable battery comprising determining whether power is supplied through an adapter, and if so, detecting a consuming current to the rechargeable battery, outputting a signal, in particular, a pulse width modulation control signal, according to a magnitude of the consuming current to the rechargeable battery and detecting a consuming current and battery recharging current. The method further includes outputting the pulse width modulation control signal according to the detected consuming current which supplies a battery recharging current, detecting continuously the consuming current and battery recharging current and adjusting and outputting the pulse width modulation control signal according to the magnitude of the detecting consuming current which supplies a battery recharging current. The method for controlling recharging current of a rechargeable battery also includes determining

whether the recharging current equals a setup current, and if not, proceeding to detect the consuming current and battery recharging current and adjusting and outputting a duty cycle of a pulse width modulation control signal, and displaying a recharging complete message if the recharging current does not equal the setup current.

5   Still another aspect of the present invention provides a method for recharging a rechargeable battery by determining whether the rechargeable battery voltage is greater than 5 volts, and if so, determining that the battery is partially discharged and performing a recharge operation according to the state of a digital device being used. Further, if the method determines that the battery voltage is less than or equal to 5 volts,

10   the method charges the battery for approximately 2 seconds at about 80 milliamps, otherwise it performs a quick recharge, or a trickle recharge.

BRIEF DESCRIPTION OF THE DRAWINGS

The above-mentioned objects and the feature of the present invention will be

15   more apparent from the following description of the preferred embodiment of the present invention when read in connection with the appended drawings, in which:

FIG. 1 is a block diagram of a digital device capable of recharging a battery according to a preferred embodiment of the present invention;

FIG. 2 is a circuit diagram showing in detail the digital device of FIG. 1;

20   FIG. 3 is a flowchart illustrating a method for controlling a pulse width modulator by the microprocessor of FIG. 2 according to the preferred embodiment of the invention;

FIG. 4 is a flowchart illustrating a method of recharging the battery in the digital device according to the preferred embodiment of the present invention; and

25   FIG. 5 is a graph showing the change of a duty cycle of a PWM signal in the microprocessor according to the variation of the consuming current.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 is a block diagram schematically showing a battery charging unit 100 for a digital device capable of recharging a rechargeable battery according to a preferred embodiment of the present invention. The battery charging unit 100 comprises a consuming current detect unit 10, a control unit 20, a recharging control unit 30, a recharging current detect unit 40, and respective loads 50 of the digital device to perform basic operations.

The consuming current detect unit 10 detects a consuming current input to the digital device through an adapter.

The recharging current detect unit 40 detects the battery recharging current as the battery is recharged.

The recharging control unit 30 regulates the consuming current to the rechargeable battery (battery) 60 (not shown) in proportion to a pulse width modulation (PWM) control signal output from the control unit 20 and the battery recharging current detected by the recharging current detect unit 40.

The control unit 20 outputs the PWM control signal to the recharging control unit 30. The PWM control signal has a duty cycle adjusted according to the consuming current detected by the consuming current detect unit 10.

FIG. 2 is a circuit diagram showing in detail the battery charging unit 100 of FIG. 1. In FIG. 2, each of the boxes enclosed by dotted lines indicates respectively the function blocks in FIG. 1.

The consuming current detect unit 10 comprises a current detecting resistor R1 for detecting the consuming current, and an operational amplifier 12 for amplifying the consuming current detected by the current detecting resistor R1. The signals from the both ends of the current detecting resistor R1 are input respectively to a noninverting terminal (+) and an inverting terminal (-) of the operational amplifier 12, and then are amplified.

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The recharging current detect unit 40 includes two current detecting resistors R2 and R3 for detecting the battery recharging current, and an operational amplifier 42 for amplifying the battery recharging current detected by the current detecting resistors R2, R3. The operational amplifier 42 compares and amplifies the signal detected by the

5   current detecting resistor R2 that is connected between the battery 60 and ground, and the signal detected by the current detecting resistor R3. Herein, the former signal is input to the noninverting terminal and the latter signal is input to the inverting terminal of the operational amplifier 42.

The recharging control unit 30 comprises an integrator 32 for smoothing the

10   PWM control signal, a switching control portion 34 for outputting a switching control signal by comparing the output signal from the integrator 32 with the battery recharging current, and a switching portion 36 for switching the received consuming current and transmitting it to the battery 60 according to the switching control signal output from the switching control portion 34. The switching control portion 34 comprises an operational

15   amplifier 34 for amplifying signals, in which the non-inverting terminal is connected to the converted DC signal of the PWM control signal output from the integrator 32, and the inverting terminal is connected to the battery recharging current detected by the recharging current detect unit 40 (i.e., the output of operational amplifier 42). In addition, the switching portion 36 comprises a transistor (TR) to respond to the output

20   signal from the operational amplifier 34.

The battery charging unit 100 further includes a display means 70 for displaying the recharging state of the battery 60. As the display means 70, a light emitting diode (LED) 70 can be used. Other display devices, well known to those skilled in the art, can also be used as display means 70.

25   The microprocessor 20 controls the overall operations of the battery charging unit 100, and specifically, the microprocessor 20 outputs the PWM control signal to the integrator 32 so as to control the recharge of the battery 60 according to the consuming current, and operates the LED 70 according to the recharging state of the battery 60.

FIG. 3 is a flowchart for illustrating in detail the process of the microprocessor in FIGs 1, 2. If DC power is supplied from the adapter (S310), the microprocessor 20 first detects the consuming current by means of the output signal from the first operational amplifier 12 that amplifies the signals of the both ends of the current detecting resistor

5   R1 (S320). With the consuming current detected, the microprocessor 20 outputs the PWM control signal to the recharging control unit 30 in accordance with the consuming current so that the recharging current is supplied to the battery 60 (S330). The integrator 32. located within the recharging control unit 30 smoothes and receives the PWM control signal and outputs a DC signal to the operational amplifier 34. The operational

10   amplifier 34 transmits the signal reduced through the resistor R4 to the base of the transistor TR, and then the transistor TR switches the consuming current that is applied from the adapter, to the battery 60 according to the DC signal output from the operational amplifier 32. The transistor TR is turned on according to the magnitude of the initial consuming current, as the consuming current increases/decreases (step S340),

15   the microprocessor 20 again outputs (continuously) the PWM signal, but the duty cycle is varied according to the increase/decrease of the detected consuming current (S350). FIG. 5 shows the change of the PWM signal duty cycle output from the microprocessor 20 as the consuming current increases/decreases. When the microprocessor 20 transmits the PWM control signal with the changed duty cycle, the transistor TR switches the

20   consuming current to the battery 60, in the amount adjusted in proportion to the changed duty cycle of the PWM control signal.

Therefore, as the consuming current is supplied to the battery 60, battery recharging is performed. Concurrently, the microprocessor 20 detects the battery recharging current while the battery 60 is recharged, using the current detecting resistor

25   R2, R3 and the third operational amplifier 42 (S340). The signal that represents the comparison between the battery recharging current and the current detected by current detecting resister R3 is input to the inverting terminal (-) of the operational amplifier 34 to be used for switching control, along with the DC signal which is output from the

integrator 32. The microprocessor 20 is able to recognize the battery recharging capacity according to the battery recharging current as detected. Accordingly, when the detected battery recharging current reaches a predetermined current level ("Yes" path from decision step S360), the microprocessor 20 displays a message through the LED 70 (S370) that battery recharging complete. If, however, the recharging current does not equal the setup current, the method returns to continuously detecting the consuming current and battery recharging current step in step S340 ("No" path from decision step S360).

FIG. 4 is a flowchart for showing the preferred embodiment of a method of recharging the battery 60 battery charging unit 100 according to an embodiment of the present invention. If the voltage of the battery 60 is more than 5V ("Yes" path from decision step S410), the microprocessor 20 determines that the battery 60 is partially discharged, and performs the recharge operation according to the state of the digital device being used. To perform the recharge operation according to the state of the digital device. The microprocessor 20 checks the consuming current, and outputs a PWM control signal according to the consuming current (S420). Next, a portion of the consuming current according to the PWM control signal is supplied to the battery 60 for recharging (S430). Note that step S430 comprises steps S432, S434 and S436., After outputting the PWM control signal in step S420, the microprocessor 20 determines if the battery recharging current is between 1000 mA~300 mA in decision step S432. If it is the microprocessor 20 flickers the LED 70 one time.

If the recharging current reaches 0.3A within 12 hours, which is a predetermined maximum recharge time, the microprocessor 20 switches to a second recharge mode ("Yes" path from decision step S432). in step S434. In step S434 the LED 70 is illuminated continuously.and after one hour of recharging the battery 60, a "recharging complete" message is displayed (S436). When recharging is completed, the LED 70 is illuminated continuously. In the event that the recharging current does not reach 0.3A within 12 hours ("No" path from decision step S432), the battery voltage is checked by

the microprocessor 20 (S442). If the battery voltage is more than 7.0V ("Yes" path from decision step S442), the LED 70 is continuously illuminated, and recharging is completed after half an hour of recharging (S444). However, if the battery voltage is not more than 7.0V ("No" path from decision step S442), an error message is displayed and

5   the recharging operation is terminated (S480).

Referring back to decision step S410, if the battery voltage is less than or equal to 5V, the microprocessor 20 performs a trickle recharge mode (S450). In a trickle recharge mode, the microprocessor 20 supplies 80 mA to the battery 60 for half an hour regardless of the operation of the digital device. If the battery voltage is more than 5V

10   after 2 seconds of the trickle recharge, a quick recharge is performed. Otherwise, the trickle recharge is continued. When the TRICKLE recharge begins (decision step S460), the microprocessor 20 flickers the LED 70. If after one half hour of trickle recharge the battery voltage is more than 5V step S420 is performed by the microprocessor 20 ("Yes" path from decision step S460). If the battery voltage is less than or equal to 5V

15   after one half hour of trickle recharge, the method proceeds to decision step S470. In decision step S470, it is determined whether the recharging current is not more than 30 mA for two seconds during the trickle recharge. If the recharging current is not more than 30 mA for 2 seconds ("Yes" path from decision step S470), an error message is displayed and the recharging operation is terminated (S480). If, however, during trickle

20   recharge the recharging current is more than 30 mA, or, it is less than 30 mA, but also for less than 2 seconds, the method continues to recheck the trickle recharge current magnitude and duration in decision step S470.

The method discussed above for battery recharging of the digital device divides the battery recharge modes into two modes according to the battery residual capacity; an

25   operation mode and a trickle mode. If the battery residual capacity is greater than a specific criteria, the operation of the digital device and the recharging thereof are performed simultaneously. Otherwise, the battery 60 is first recharged to exceed the criteria, and then, the operation of the digital device and recharging thereof are

performed simultaneously.

The above-described embodiments do not limit the variation on the number of LEDs 70, the number of times of illuminating and flickering, and setup time that can be implemented in the battery charging unit 100. Therefore, a plurality of the LEDs 70 can

5   be applied for displaying the recharging state of the battery 60, and it is possible to apply a different number of times of flickering the LED 70, as well as a different setup time. In addition various states can be displayed through the LED 70, such as errors occurring during the battery recharging caused by overcurrent, overvoltage, battery defective, and suspension of recharging.

10   The battery charging unit 100 can operate and recharge the battery 60 simultaneously with the power supplied from the adapter. Embodiments of the present invention can reduce the material costs as well as the number of parts, since the control unit controls the recharging operation instead of the high-priced IC.

In addition, since the control unit 20 controls the recharging operation, errors

15   such as overcurrent, overvoltage, battery-defective, suspension, as well as completion of recharging, are freely displayed on the display means. Therefore, users can recognize the recharging state of the battery 60 easily and conveniently.

While the invention has been shown and described with reference to a preferred embodiment thereof, it will be understood by those skilled in the art that various changes

20   in form and details may be made therein without departing from the sprit and scope of the invention as defined by the appended claims.